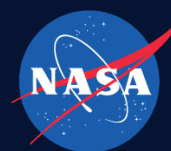


# Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations

Mission Directorate (HEOMD)



## ABSTRACT

The project enables a largely mission-independent, cradle-to-grave-to-cradle approach to minimize logistics contributions to total mission architecture mass. The goals are to engineer logistics materials, common crew consumables, and container configurations to meet five basic goals. When these five goals are integrated across a mission, they will reduce ISS-equivalent packaging volume by 50%.

The Logistics Reduction Project is the follow-on to this project.

## ANTICIPATED BENEFITS

### To NASA funded missions:

All human space missions, regardless of destination, require significant logistical mass and volume that is strongly proportional to mission duration. As exploration missions lengthen in distance and duration, reduction of these logistics requirements becomes even more important since they may all have to be loaded on a single launch vehicle. This project works to reduce initial mass and volume of supplies or reuse items that have been launched.

### To NASA unfunded & planned missions:

All human space missions, regardless of destination, require significant logistical mass and volume that is strongly proportional to mission duration. As exploration missions lengthen in distance and duration, reduction of these logistics requirements becomes even more important since they may all have to be loaded on a single launch vehicle. This project works to reduce initial mass and volume of supplies or reuse items that have been launched.

### To other government agencies:

Technologies developed under this project could also be utilized by other government agencies whose personnel live and work in

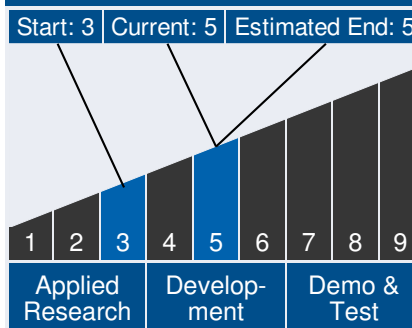


LRR Turns Trash from Problem to Opportunity

## Table of Contents

Abstract	1
Anticipated Benefits	1
Technology Maturity	1
Management Team	1
Detailed Description	2
Technology Areas	2
U.S. Work Locations and Key Partners	5
Image Gallery	6
Details for Technology 1	6

## Technology Maturity



## Management Team

### Program Director:

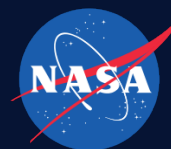
- Jason Crusan

*Continued on following page.*

# Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations

Mission Directorate (HEOMD)



extreme remote environments, such as the military, the National Science Foundation research stations, etc.

## To the commercial space industry:

These technologies may have broad use for potential commercial providers of future exploration systems, providing benefits for reduction of logistics requirements.

## To the nation:

The project can enable sustainable human long-term space exploration and support personnel living and working in extreme remote environments. Terrestrial technology spin-offs may also include new environmentally friendly technologies in areas such as clothing systems, reuse of items and waste-to-energy.

## DETAILED DESCRIPTION

The Advanced Exploration Systems (AES) Logistics Reduction and Repurposing (LRR) project will enable a mission-independent cradle-to-grave-to-cradle approach to minimize logistics contributions to total mission architecture mass. The goals of LRR are to systematically engineer common crew consumables, container configurations, and waste management to meet five basic goals:

1. Direct reduction of logistical mass.
2. Improved automated tracking of logistical items in packaging containers and cabin environments to allow denser logistical packaging at launch and to save on-orbit crew time.
3. Direct reusing and repurposing of logistical items to avoid flying separate items to meet both functions.
4. Reprocessing of logistical items to provide a secondary function, increase habitable volume, and enhance life support closure.
5. Deconstruction of logistical materials and reconstruction to primary gases or as a means of reducing waste volume through venting.

## Management Team (cont.)

### Program Executive:

- Barry Epstein

### Project Manager:

- James Broyan

## Technology Areas

### Primary Technology Area:

Human Exploration Destination Systems (TA 7)

- └ Habitat Systems (TA 7.4)
  - └ Integrated Habitat Systems (TA 7.4.1)
    - └ Bioregenerative Resources (TA 7.4.1.11)

### Secondary Technology Area:

Human Exploration Destination Systems (TA 7)

- └ Sustainability and Supportability (TA 7.2)
  - └ Autonomous Logistics Management (TA 7.2.1)
    - └ Multipurpose Cargo Transfer Bag (TA 7.2.1.9)

*Continued on following page.*

# Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations  
Mission Directorate (HEOMD)



The goals of the Logistics project will be accomplished through five hardware tasks plus a strong systems engineering analysis and integration function. The five hardware oriented tasks are:

## Technology Areas (cont.)

Human Health, Life Support, and Habitation Systems (TA 6)

- └ Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
- └ Extravehicular Activity Systems (TA 6.2)
  - └ Pressure Garment (TA 6.2.1)
    - └ Reusable Drink/Nutrition Bag (TA 6.2.1.10)
  - └ Portable Life Support System (TA 6.2.2)
    - └ Closed-Loop Consumable CO<sub>2</sub> Removal, Low Mass (TA 6.2.2.7)

*Continued on following page.*

# Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations

Mission Directorate (HEOMD)



1. Use of an Advanced Clothing System (ACS) to directly reduce the mass and volume of clothing needed to be flown. Antimicrobial treatments are applied to current and lighter weight commercial-off-the-shelf (COTS) exercise clothing to investigate if they could be used for longer periods of time. Longer wear clothing will change the break-even point for laundering (vs. clothing disposal) sufficiently to delay development until Mars surface missions are planned.
2. Use of Autonomous Logistics Management (ALM) methods using radio frequency identification (RFID) technologies and 3D localization and complex event processing to enable automatic inventory tracking as resources move around a vehicle. ALM will reduce crew time in locating stored items in densely packed areas and enable the location of lost items.
3. Repurposing of logistics-to-living (L2L) multipurpose cargo transfer bags (MCTBs) for on-orbit outfitting. MCTBs can be used for constructing crew quarters, privacy or sound-adsorbing partitions, contingency water storage or waste water processing units, and dense-area RFID enclosures for ALM. Reuse of the MCTB logistics carriers prevents the need to fly separate items.
4. Conversion of waste and used logistical items to useable products with a heat melt compactor (HMC). Waste items are heated and mechanically compacted into stable tiles that can be used for radiation shielding. Additionally, water is recovered for life support processing. For a one-year mission, it is estimated that HMC could recover ~10 cubic meters of habitable volume, produce over 800 kg of radiation shielding tiles, and recover 230-720 kg of water.

*Continued on following page.*

## Technology Areas (cont.)

Human Exploration Destination Systems (TA 7)

- └ Sustainability and Supportability (TA 7.2)
  - └ Autonomous Logistics Management (TA 7.2.1)
    - └ Propellant Scavenging (TA 7.2.1.1)
    - └ Flexible, Vacuum-Rated Liquid Storage Bags (TA 7.2.1.2)
    - └ Power Scavenged Wireless Sensor Tag Systems (TA 7.2.1.3)
    - └ Dense Zone Technology (Radio Frequency Identification Enclosure) (TA 7.2.1.4)
    - └ Sparse Zone Technology (TA 7.2.1.5)
    - └ Logistics Complex Event Processing (TA 7.2.1.6)
    - └ Six Degree of Freedom Logistics Tag System (TA 7.2.1.7)
    - └ Packaging Foam Additive Printer Feedstock (TA 7.2.1.8)

*Continued on following page.*

# Logistics Reduction and Repurposing Project

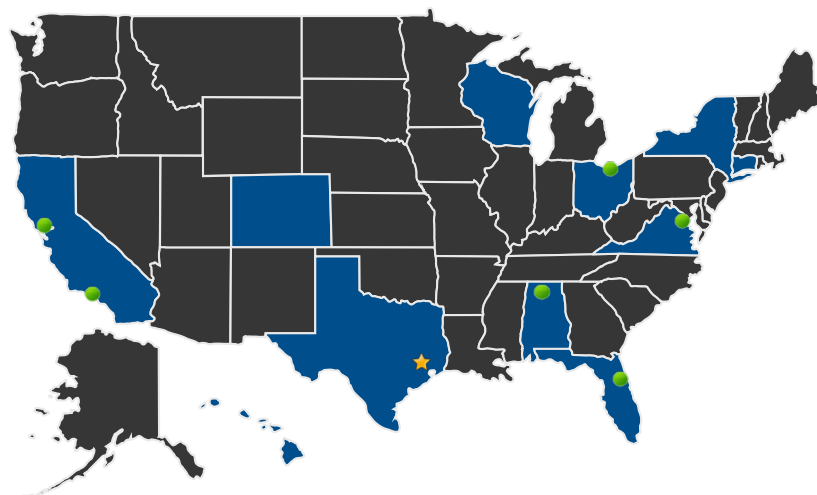
Advanced Exploration Systems Program | Human Exploration And Operations

Mission Directorate (HEOMD)



5. Reformulation of trash to gas (TtG) to make propellant from waste products. Thermochemical processes are used to deconstruct trash to its hydrocarbon constituents and recombine it to form methane and other gases useful for propellant or life support. For a one year mission, it is estimated that TtG could produce up to 1500 kg of methane from trash.

## U.S. WORK LOCATIONS AND KEY PARTNERS



■ U.S. States  
With Work

★ **Lead Center:**  
Johnson Space Center

### ● Supporting Centers:

- Ames Research Center
- Glenn Research Center
- Jet Propulsion Laboratory
- Johnson Space Center
- Kennedy Space Center
- Marshall Space Flight Center
- NASA Headquarters

### Technology Areas (cont.)

Modeling, Simulation, Information Technology and Processing (TA 11)

- └ Information Processing (TA 11.4)
  - └ Advanced Mission Systems (TA 11.4.5)
    - └ Multi-Agent Master Framework (TA 11.4.5.3)

Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

Ground and Launch Systems (TA 13)

- └ Operational Life-Cycle (TA 13.1)
  - └ Logistics (TA 13.1.4)
    - └ Digital Product Lifecycle Management (TA 13.1.4.1)
    - └ Supply Chain and Supplier Economic Resilience Modeling (TA 13.1.4.2)
    - └ Additive Manufacturing as Replacement for Original Equipment Manufacturer (OEM) Spare Parts (TA 13.1.4.3)

# Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations  
Mission Directorate (HEOMD)



## Other Organizations Performing Work:

- Advanced Fuel Research, Inc. (East Hartford, CT)
- Cleveland State University
- Cornell University
- Manhattan College
- Orbital Technologies Corporation (ORBITEC)
- Pioneer Astronautics (Lakewood, CO)
- Precision Combustion, Inc. (North Haven, CT)
- TDA Research, Inc. (Wheat Ridge, CO)
- United Technologies Aerospace Systems
- University of Alabama, Huntsville
- University of Hawaii (Honolulu, HI)

## IMAGE GALLERY

---



*Heat Melt Compactor Makes Stable  
Tiles from Trash*

## DETAILS FOR TECHNOLOGY 1

---

### Technology Title

Logistics Reduction and Repurposing Project

### Technology Description

This technology is categorized as a hardware system for manned spaceflight

Advanced Clothing System (ACS) researchers are working to directly reduce the mass and volume of clothing flown in space. Antimicrobial treatments have been applied to current and lighter weight commercial-off-the-shelf (COTS) exercise clothing in a ground based experiment to investigate if they could be used for longer periods of time. The best performers were selected for a successful experiment on the International Space Station (ISS). A laundry trade-off study was conducted to quantify how longer-wear clothing changes the break-even point for laundering vs.

# Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations

Mission Directorate (HEOMD)



clothing disposal.

Autonomous Logistics Management (ALM) researchers are implementing methods using radio frequency identification (RFID) technologies and 3D localization and complex event processing to enable automatic inventory tracking as resources move around a vehicle. ALM will reduce crew time in locating stored items in densely packed areas and enable the location of lost items.

Logistics-to-living (L2L) allows multipurpose cargo transfer bags (MCTBs) to be repurposed for on-orbit outfitting. MCTBs have been used for constructing crew quarters, privacy or sound-adsorbing partitions, contingency water storage, waste water processing units, and dense-area RFID enclosures for ALM. Reuse of the MCTB logistics carriers prevents the need to fly separate items.

Researchers are also converting waste and used logistical items to useable products with a heat melt compactor (HMC). Items are heated and mechanically compacted into stable tiles that can be used for radiation shielding. Additionally, water is recovered for life support processing. For a one-year mission, it is estimated that HMC could recover ~10 cubic meters of habitable volume, produce over 800 kg of radiation shielding tiles, and recover 230-720 kg of water.

Trash to gas (TtG) researchers are making propellant from waste products. Thermochemical processes are used to deconstruct trash to its hydrocarbon constituents and recombine it to form methane and other gases useful for propellant or life support. For a one year mission, it is estimated that TtG could produce up to 1500 kg of methane from trash. A half-dozen processes were evaluated experimentally and analytically and steam reformation was selected as the technology to further develop for space exploration.

Habitation engineers are working on a Universal Waste Management System, a compact commode for the smaller volumes of exploration vehicles. Other improvements of this system are a simpler design and easier maintenance/cleaning.

## Capabilities Provided

This technology enables:

- Conversion of logistical items to useable products via heat melt compactor (HMC) processing.
- Conversion of trash to supply gas (TtG) to make propellant from waste products.
- Use of an Advanced Clothing System (ACS) to reduce mass, volume, and flammability.
- Use of logistics-to-living (L2L or LTL) to repurpose launch packaging and containers.
- Improved automated tracking of logistical items in packaging containers and cabin environments to allow denser logistical packaging at launch and to save on-orbit crew time.

## Potential Applications

Besides in space, the five technologies developed under this project could potentially be used

## Logistics Reduction and Repurposing Project

Advanced Exploration Systems Program | Human Exploration And Operations  
Mission Directorate (HEOMD)



where personnel live and work in extreme remote environments, such as the military, the National Science Foundation research stations, etc. Advanced Clothing Systems would benefit any long-duration operation with limited logistics transportation or stowage capacity. This is accomplished by extending the use of clothing before it has to be laundered or replaced. Autonomous Logistics Management would allow automatic tracking of inventory and reduce personnel time in locating tagged items. Technologies such as the Heat Melt Compactor and Trash to Gas would reduce the volume occupied by trash to improve space utilization and recover water or to generate methane from the trash as a resource.